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The Action of Micro-Organ-
isms upon Surgical Wounds,
with Demonstrations.

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To Dr. J. B. Hunter
Kind regards of the
author.



THE ACTION OF MICRO-ORGANISMS UPON SURGICAL WOUNDS, WITH DEMONSTRATIONS.

By FREDERIC S. DENNIS, M. D., of New York County.

Read November 19, 1885.

TEN years ago this winter I published an article on the treatment of wounds, in which was mentioned the important fact that putrefactive suppuration was a species of fermentation produced by microscopic organisms. In my present paper I shall endeavor to show practically what was then advanced theoretically. Much of my attention has been directed to the ætiology of putrefaction in wounds, and my present contribution will exhibit the results of some practical work performed in the Carnegie Laboratory.

I shall show the cultures of these different varieties of micro-organisms which affect surgical wounds, using as culture-media Koch's sterilized jelly, blood serum, infusions of beef and turnip, bread-paste, and potatoes. Following the demonstrations of the micro-organisms which are found in pus, water, earth and air, I shall next exhibit the specific micro-organisms which infect special surgical wounds, and close by offering some practical observations in regard to wound treatment based on the conclusions which have been derived from a study of the life-history of these various cultures. Three large metropolitan hospitals have furnished the opportunities for my work, and I trust to have used them aright.

During the past few years there has been a great controversy among surgeons in reference to the cause of septic infection in surgical wounds. Some claim that the micro-organisms are present in the air, and that if these can be prevented from com-



ing in contact with a wound no decomposition or infection can occur. Others, again, claim that the sepsis is not caused by micro-organisms in the air, and that air itself in contact with a wound will not produce decomposition. Both of these schools of surgeons have been in open conflict for years, and both teach in accordance with their own views. So distinct is the line of demarcation between them that the one teaches nothing but antiseptics, the other everything else but antiseptics. The time is now ripe for a third class, who, while representing advanced views in surgical pathology, are still loath to ignore all the traditions of the learned masters of our art. This last school will accept the theory of septic infection as the result of putrefaction, and will direct their treatment to the prevention of supuration. They will not believe, indeed, that all the success of surgery is to be based entirely upon the acceptance and practice of this one great principle of antiseptics. They will not eliminate such great principles as physiological rest, position of wounded part, bodily comfort, immunity from pain, special therapeutical treatment, attention to the hygienic surroundings of the patient, regulation of the diet, the application of suitable constitutional remedies, and other essentials which readily suggest themselves without the naming. These and like details, trivial though they may seem, contribute to success, and indicate the necessity of an unbiased judgment. Our forefathers and our contemporaries must join hands.

For the sake of convenience, I shall divide my subject as follows:

- I. The existence of micro-organisms.
- II. The action of these micro-organisms upon fluids, solids, inorganic matter and living tissues.
- III. The specific action of certain micro-organisms as the cause of certain surgical diseases.
- IV. The methods adopted by the surgeon for the destruction of the micro-organisms in wounds.

In discussing the relations which micro-organisms bear to surgical diseases, the fact must never be lost sight of that micro-organisms may exist in the body independently of any morbid

action. The entire cutaneous surface, the mucous surfaces, the respiratory organs, the alimentary canal, are covered and filled with millions of micro-organisms; but the deeper tissues escape until some exciting cause develops them. The normal tissues are impregnable, as a rule, against these "unseen enemies"; but let the standard vitality of the deeper tissues become impaired, or a secretion altered, and you then have prepared at once a suitable hot-bed for the lodgment and multiplication of these dreaded agents of destruction.

In demonstrating the existence of micro-organisms, I do not propose now to discuss the effects of their presence upon any inorganic substance, or upon any living tissue. The proof of their existence, however, is necessary before a reference to their action upon tissues. I have, therefore, thought best to make such a separation of the subject, for the purpose of making the great principles which underlie the existence of micro-organisms more evident. I fully appreciate the difficulty of my task.

I shall now place a drop of pus upon this cover-glass, and then rub it against another clean cover-glass, and the drop of pus becomes spread out in the form of a thin, dry film. I now submerge the cover-glass under a solution of gentian violet for two minutes; this stains the film purple; next, I submerge the same cover-glass under a solution of iodine dissolved in iodide of potash, which precipitates the stain in the micro-organisms, but not in the pus; next, I wash the cover-glass in a little absolute alcohol for two or three minutes, and this washes the stain out of everything but the micro-organisms; next, I dip the cover-glass in eosin which stains pus red, but does not affect the micro-organisms, and thus I get a contrast color. This method is known as Gram's, and is a most useful and simple one to be employed. The pus corpuscles are stained red, while the micrococci, or the micro-organisms in the specimen, are stained a violet color. I know that these micro-organisms were once living, because they have been cultivated in a suitable soil, and are growing here in this jelly.

Let me now in another way show the existence of micro-organisms; instead of taking pus, let me take ordinary drinking

water. Let this water stand for a few days in this test-tube, and you will have a sediment at the bottom, which, if put under the microscope, will be found to be swarming with millions of micro-organisms. This is, however, an unsatisfactory proof, for, except to adepts, it is difficult to distinguish living organisms from *débris*, foreign bodies, vegetable matter, and the like, found in drinking water in such abundance.

The most accurate, and at the same time the most scientific, test is by means of Koch's sterilized jelly spread out upon a thin plate of glass. I have here a small tripod which is so constructed as to be capable of being

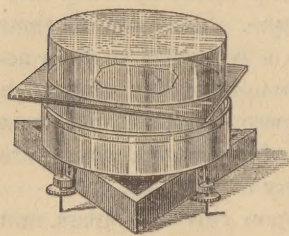


FIG. 1.

made perfectly level, and to indicate any deviation toward the slightest angle. This desideratum is secured by the carpenter's level, which is attached to the frame. This trouble is taken in order to have a film of jelly uniformly spread out over the surface of the glass plate. Having carefully disinfected and thoroughly

sterilized the plate, I now take this test-tube, which is about one third full of Koch's sterilized jelly, and add three drops of Croton water, which is introduced into the jelly by means of a clean pipette. This experiment should be performed in a place where there are no draughts. For the purpose of mixing the jelly and the water, I shake the tube well. I now pour over the glass plate the contents of the test-tube, and immediately place over the jelly the bell-jar. Upon these plates thus prepared can be seen a large number of colonies of micro-organisms, which have developed and multiplied from those contained in three drops of Croton water.

I am indebted to Dr. H. M. Biggs, of the Carnegie Laboratory, for an account of the analysis of water from Plymouth during the recent epidemic of typhoid fever. He visited that place to investigate the cause of the epidemic. In the report he states that the chemical examination of the different specimens of water collected at Plymouth, made by Professor A. A. Brene-

man, showed that the water from the Davis well contained evidences of most serious contamination with putrescible organic matter. This well was situated on the bank of the reservoir, near the house where the first case of typhoid fever occurred. Specimens of the water, which had been collected in sterilized bottles, with the most careful precautions, were examined for the presence of micro-organisms, with the hope that the typhoid bacillus might be found, and that thus could be shown the direct relationship supposed to exist between the micro-organisms present in the contaminated water and those found after death in the different organs in this disease. Cultures were made in the ordinary manner upon glass plates with every possible precaution. Micro-organisms of many different species were found to be present in enormous numbers. The number present was so large that it was found necessary to dilute the water with five hundred to seven hundred parts of gelatine in order to obtain plate-cultures that were at all satisfactory. Then, notwithstanding this extensive dilution, the number of colonies developing in these plates was exceedingly large. Thirteen or fourteen different varieties of micro-organisms were thus isolated from the water, comprising a number of varieties of each of the forms of micrococci, micro-bacteria, and bacilli, many of which were organisms of putrefaction. No form could be found among these which corresponded, as to its morphology and growth in different culture-media, to the cultures of the typhoid bacilli which were used for controls, and which had been obtained from Germany. More recently cultures have been received from Koch's laboratory, in Berlin, and it was then found that the original cultures were not genuine typhoid bacilli, so that the observations on this point were valueless. However, the presence of the large number of micro-organisms of different species, many of them being organisms of putrefaction, is very significant when taken in connection with the results of the chemical analysis of the water, which showed the presence of a large amount of putrescible organic matter.

The experiments to obtain micro-organisms in dirt are conducted in the following manner. I have here a sterilized glass

chamber which is lined by blotting-paper soaked in bichloride of mercury, and which chamber has been subjected to the same treatment as the glass plate in the previous experiment. This glass chamber has been allowed to stand for twelve hours, so as to permit the atmospheric organisms therein to gravitate to the bottom. The glass plate in the glass chamber is now covered with a thin film of Koch's sterilized jelly, and then the soil or earth to be examined is sprinkled in transverse rows upon the plate. Upon this plate I have sprinkled some dirt from the streets of New York, and from the few particles on the end of a knife-blade there are innumerable points of infection. I have also sprinkled upon another glass plate some dirt which was taken from the ground one hundred feet deep where an Artesian well was in the process of construction. The difference in the two plates is accounted for by the fact that one plate is sprinkled by surface soil, the other by soil obtained from a great depth. The fact that these points of infection upon the plates are due to micro-organisms can be proved by examination with the microscope, which shows the morphological appearances of living organisms, and further by cultivation of these germs upon a nutrient soil.

Next, let us study the existence of micro-organisms in the air.

This subject is one of great practical importance, not only from a sanitary, but especially from a surgical point of view. I am indebted to Professor John Chiene, of Edinburgh, and to his assistant, Mr. Hare, for valuable laboratory facilities extended to me during the past summer while in Scotland.

These glass capsules, which contain Koch's sterilized jelly, have been used for the purpose of testing the purity of the air. The idea suggested itself to me to make some observations in regard to the quality of the air at mid-ocean on the Atlantic. Pasteur made some observations in the Alps, from the Mer de Glace, near the Montanvert. He exposed twenty flasks containing organic infusions to glacier air; only one out of twenty flasks showed signs of the presence of micro-organisms, and, when he descended to the plains below, eight out of twenty flasks became turbid from the presence of micro-organisms. In accordance

with these observations I undertook the task of testing the quality of the air nearly a thousand miles from land, and of inquiring into its power to produce putrefaction. I first exposed a capsule in the state-room upon the main deck of an ocean steamer. The sterilized jelly was exposed to the air of the state-room only fifteen minutes during one afternoon. To my astonishment I found within eighteen hours that over five hundred points of infection had developed from the contaminated air in the state-room. I have here the same capsule preserved with great care, and there can be seen upon the surface of the jelly over five hundred points of infection. I then selected another capsule which was prepared weeks previous in the same way, and which was sterilized as all the others were at the time of preparation and at the time of the observation. This second capsule was subjected to the same tests in my own cabin upon the promenade deck, where the circulation of air was free and direct from the ocean with nothing intervening to destroy its quality. There were two doors, two port-holes, and a large skylight above, all of which afforded free access of air from the sea. After fifteen minutes' exposure of the jelly twenty-four hours afterward, I found no points of infection upon the surface of the capsule. Surprised at this phenomenon, I selected a third capsule which, like the second, did not show any evidences of the presence of micro-organisms at the time of the observation. These two capsules after ten days began to show slight traces of infection, to the number of five or six points; but the contrast from the one in the cabin below, where in eighteen hours five hundred points of infection developed, and those on deck, where in ten days only five or six points of infection were visible, should awaken the attention of steam-ship companies toward a more thorough method of ventilation. I then placed in the stoker's room capsules, and with a temperature of 140° Fahr. the quality of the air was found to be immeasurably purer than in the passengers' state-rooms. However, the capsules in the stoker's room, in the front of the furnaces, gave evidences of infection after a few days. Finally I tested the air from the bow of the ship at the same time as these other observations

were made. The capsule was exposed fifteen minutes, and I held it over the ship at the very bow, and with the wind blowing toward me, so that no germs from the ship nor from my person could possibly reach the jelly. The result of this observation was perfect. The jelly which was exposed to the air at that time, one thousand miles from any land, is as uncontaminated this the nineteenth day of November as when it was sterilized in Edinburgh last August. This is the first experimentation ever recorded in this line, so far as I know, in which special reference was had to the presence of micro-organisms in the air in the middle of the Atlantic. A single observation, I admit, is insufficient upon which to base conclusions regarding the purity of any air, yet is significant when taken in connection with the others which were conducted in mid-ocean. Place this one side by side with the tests made by Pasteur, of the air blowing over fields of ice for many miles, and you can not shut your eyes upon an impressive fact. In like manner, with the kind assistance of Dr. Frank Grauer, I have examined the air in the different wards of the third surgical division of Bellevue Hospital, also in the Sturgis pavilion, in the Erysipelas pavilion, in the Morgue, in the dissecting-room, in cellars, and upon the tops of private dwellings, and the results of these experiments, counting up over one hundred and fifty, as well as representing many weeks of labor, are now before this Association for adjudication.

Pasteur began a series of experiments, a passing reference to which has already been made, with bulbs which contained infusions that had been sterilized. He opened twenty-four such bulbs as I have here upon Mount Poupet, which is eight hundred and fifty metres above the sea-level. He also opened twenty upon the Montanvert, near the Mer de Glace, which was two thousand metres above the sea-level. In his report he states that out of the twenty-four opened on the Jura five only were infected, and of the twenty opened upon the Montanvert one alone became turbid. Pasteur suggests that, if the bulbs were exposed at a great height by an aeronaut, no germs would be found in the air to cause turbidity of the infusions. My exposure of the Koch's sterilized jelly nearly a thousand miles

from land accords with the view which Pasteur then held, although up to the time of my experiment no data had been furnished.

When it is considered, by an attempted mathematical calculation which I have made, that millions and millions and millions of these micro-organisms infect the air in which operations are daily performed in our hospital wards, and when, further, the other fact is demonstrated that these germs are the agents of putrefaction, or the "unseen enemies" which cross our path, is it not a subject of mighty importance for us to study how to protect our patients from the forces which can turn the battle for life or death in any operation? It is obvious, from an observation of these various capsules and flasks and glass jars and the tray of sterilized potatoes and the boxes, that the germs in the air are not evenly distributed, but that they fall upon the jelly in clouds, and that here and there the jelly is free from any infection. In this glass cylinder, which has been most elaborately and carefully prepared to insure success in the experiment, is deposited a layer of Koch's

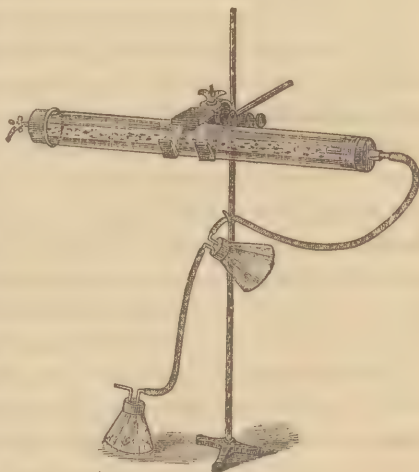


FIG. 2.

sterilized jelly, and over the nutrient bed the air is forced slowly by a vacuum produced by syphon action, and in the horizontal column of air germs fall upon the nutrient pabulum below, and the points of infection are thus distributed unevenly over the surface. There are, therefore, aërial interspaces between bacterial clouds where the spaces are free from germs, and this phenomenon serves to explain the important clinical fact that, if a wound be exposed in a ward for a moment, it may be just as

a bacterial cloud has passed, and in the interspace the wound has no germs to fall upon it, and hence there is escape from infection. While this fact explains the absence of infection in one wound and its presence in another in the same ward, it also serves to teach us to be constantly on the alert against contamination. A further examination of these several trays shows also that the micro-organisms are not found uniformly in the air; for in some of these glass vessels there are to be seen many points of infection, while in others the points of infection are absent. These glass vessels were exposed at the same time, under the same circumstances, upon the same table, and in the same air, and yet you see some are infected and others escape.

The most common variety of living organisms found upon the beef infusion is the *penicillium glaucum*. This is also seen upon Koch's jelly, which it partially liquifies, and upon the surface the mold appears in the form of a zone, which is usually green, with wide variations in the shade. Instead of the zone, a velvety growth is sometimes observed, and the mold appears like a piece of absorbent cotton which might have fallen upon the jelly. This mold grows upon the surface of the jelly or infusion, and must not be mistaken for various organisms which may alter the consistence and color of the jelly below the surface and in the substance of the jelly. In imperfectly sterilized jelly or fluids, the presence of organisms often leads the observer into error; therefore, too great care can not be exercised in their preparation. With all my precautions, I have failed in a series of interesting experiments by reason of the jelly being impregnated with germs in the air in the laboratory while in the act of pouring the jelly from a sterilized vessel into the capsules. The jelly was exposed to the infection for only a few seconds. When the capsules are filled, as they must be, amid the greatest antiseptic safeguards, they are suitable for experimentation.

Instead of the *penicillium glaucum*, bacteria may be found in great abundance. In some cases, as is illustrated by these flasks, bacteria seem to destroy the mold, whereas, in other cases, the *penicillum glaucum* annihilates the bacteria. The presence of

the one to the exclusion of the other depends upon the reaction of the fluid, the character of the air in which it is exposed, as well as upon the variety of bacteria.¹ Mycelia may be found in the bottom of the fluid, and this mold may occupy the fluid to the exclusion of all other forms of living organisms.

Most of our antiseptic solutions, carbolic acid notably, are acids which act as better germicides than alkaline solutions, at least as regards the action of bacteria. The question as to the reaction of the antiseptic solution in its influence upon the development of micro-organisms is one which is only partially settled. Daily experiments are made, observations recorded, and results obtained. Every antiseptic solution of merit has many advantages as well as many disadvantages, and experimentation must fix the value of one over the other. I have found, for example, that certain antiseptic solutions, if employed to moisten bread-paste upon which cultures have been made, will often cause the death of a special micro-organism, but other varieties will develop and thrive in their stead. What is the best antiseptic is still an unsolved problem.

The existence of micro-organisms having been demonstrated in pus, water, earth, air, and other media, it now seems pertinent to direct attention to a consideration of some of the most important characteristics of these living micro-organisms. This is necessary in order to better understand the action of these micro-organisms upon living tissues. An anatomical description, therefore, of these germs, together with some remarks upon their characteristics, will be given before discussing their action.

A micro-organism consists essentially of three parts.

(1) Cellulose membrane. (2) Protoplasm. (3) Cilia or flagella.

(1) The cellulose membrane, which resists the action of acids and alkalies, is exceedingly delicate and thin in texture. This membrane enables the germ to resist the action of acids and alkalies.

¹ Bacteria grow best in either neutral or a slightly alkaline fluid, and penicillium glaucum thrives best in an acid infusion. Hence, if germs are sown in equal quantities into an acid or an alkaline fluid, the growth of the germ will be influenced by the fact of its adaptability to the reaction of the fluid.

(2) Protoplasm. Within the cellulose membrane is a mass of protoplasm which is generally colorless and always nitrogenous. Sometimes it is colored with some pigment, and it is often granular.

(3) Cilia or flagella are found in certain forms of bacteria and bacilli. The profession of medicine is indebted to the Rev. Mr. Dallinger, of Sheffield, for the demonstration of the cilia or flagella. One of the greatest discoveries in bacteria has thus been made by one not of our own profession.

Requirements of Micro-organisms.

Nutrition, warmth, moisture, are three essential conditions for the growth of micro-organisms.

First, moisture. Water is absolutely necessary; without it the movements of bacteria and bacilli are arrested, and the physiological functions are destroyed.

Second, nutrition. Nitrogen in some form is essential to the growth of the protoplasm of the micro-organism; the nitrogen may come from the albuminous compounds through the process of putrefaction or from nitric acid in the ammonia. Carbon is also necessary for the growth of germs.

Oxygen is an important element for the life of aerobic, but not for the life of anaerobic micro-organisms. In other words, oxygen is necessary to some and fatal to others. The vibrio of butyric acid is an example of a micro-organism which lives and multiplies with little or no oxygen; air, in fact, destroys its action and arrests the butyric acid fermentation which this vibrio produces.

The mycoderma aceti, of which I have here a beautiful example taken from a decanter upon my sideboard, is a micro-organism which requires oxygen for its growth and multiplication. This germ is the one concerned in the manufacture of vinegar. If this wine is hermetically sealed and then exposed to a heat 60° Centigrade the wine will never acetify. But if the wine is uncorked, and it is exposed to the action of ordinary air, the acetification will follow as it has in this bottle. The mycoderma aceti will thrive upon the surface of wine in the

form of a thin floating film, but it can not live below the surface owing to the absence of air. Oxygen seems necessary to spore development. The spores of anthrax bacilli will never germinate except they are freely exposed to oxygen.

Now as to warmth. A temperature of blood-heat, or 98° Fahr., is found to be the most favorable to the life of micro-organisms. Great extremes are fatal to their life. 122° Fahr. destroys bacterium termo. 176° Fahr. will not destroy the spores of bacilli; in fact, they are not prevented from germination by a temperature of even 212° Fahr. A temperature of 32° Fahr., or that of freezing-point, will check this development of the germs, although -123° Fahr. has failed to kill the spores of bacilli. Great alternations from a very high to a very low temperature are apt to be fatal.

The presentation of a suitable classification of micro-organisms is for obvious reasons very difficult. The one which seems to me the best adapted for our purpose is that of Cohn, somewhat modified, and in this classification I will take the liberty of adding some germs which, though having a special relation to surgery, are not included in Cohn's list, and which have never been heretofore described in any work. The classification, though it is numerically great, can be verified in nearly every instance by a reference to these cultures upon the table, for nearly every germ, without exception, is found in this list, in a state of cultivation upon the numerous sterilized surfaces either contained in flasks or exposed upon a surface.

I. *Sphero-bacteria*.—Bacteria in spheres.

II. *Micro-bacteria*.—Bacteria in short rods.

III. *Desmo-bacteria*.—Bacteria in straight filaments.

IV. *Spiro-bacteria*.—Bacteria in spiral filaments.

V. *Fungi*.

No. I, II, III, IV, belong to Schizomycetes.

No. V belong to Blastomycetes.

I. *Sphero-bacteria*:

A. Chromogenes	{	Micrococcus prodigiosus. Micrococcus luteus. Micrococcus aurantiacus.
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- | | | |
|---------------|---|-----------------------------|
| B. Zymogenes | { | Micrococcus crepusculum. |
| | { | Micrococcus ureæ. |
| | { | Micrococcus stringy wine. |
| C. Pathogenes | { | Micrococcus erysipelatosus. |
| | { | Micrococcus gonorrhœa. |
| | { | Micrococcus septicus. |

II. *Micro-bacteria* :

- | | | |
|----------------|---|---------------------------------------|
| A. Chromogenes | { | 1. Bacterium æruginosum. |
| | { | 2. Bacterium xanthinum. |
| B. Zymogenes | { | 1. Bacterium termo. |
| | { | 2. Bacterium lactis. |
| | { | 3. Bacterium aceti. |
| C. Pathogenes | { | 1. Bacterium of septicæmia (Davaine). |
| | { | 2. Bacterium of septicæmia (Koch). |

III. *Desmo-bacteria* :

- | | | |
|----------------|---|---------------------------|
| A. Chromogenes | { | 1. Bacillus ruber. |
| | { | 2. Bacillus of blue milk. |
| | { | 3. Bacillus auranticus. |
| B. Zymogenes | { | 1. Bacillus subtilis. |
| | { | 2. Bacillus septicus. |
| | { | 3. Bacillus ulna. |
| C. Pathogenes | { | 1. Bacillus anthracis. |
| | { | 2. Bacillus tuberculosis. |
| | { | 3. Bacillus of glanders. |

- | | | |
|-----------------------------|---|-----------------|
| IV. <i>Spiro-bacteria</i> . | { | 1. Vibrio. |
| | { | 2. Spero-chætæ. |
| | { | 3. Spirillum. |

- | | | | | |
|-------------------|---|-----------------|---------------------|-------------------------|
| V. <i>Fungi</i> . | { | I. Mold fungi | { | 1. Penicillium glaucum. |
| | | | { | 2. Aspergillus { |
| | | | | albus. |
| | | | | niger. |
| | | repens. | | |
| | { | II. Yeast fungi | { | 1. Torula cerevisiæ. |
| { | | | 2. Mycoderma aceti. | |

Micrococci.—Micrococci are small oval or round micro-organisms which possess no cilia. They differ from bacteria and bacilli by the absence of the cilia or flagella, which permit a certain amount of locomotion to bacteria and bacilli.

The size of micrococci varies from a half of μ to three μ . Micrococci multiply by fission, and not by spores or germination. If a single micrococcus is examined under the microscope it will be found oval or round, and its size is within the dimensions already given. This micro-organism would be termed a monococcus.

This monococcus multiplies by fission or division by a central cleavage. The monococcus becomes elongated, and then centrally constricted, and in this manner a monococcus is converted by simple division into a diplococcus.

It is to be noticed that the micrococci, while they divide into sections, are never rod-shaped, as is the case in bacilli. The two segments from the single monococcus are still invested by a cellulose membrane, which forms a narrow bridge between the two elements. This cellulose membrane is the original investing membrane of the micrococcus. The two elements, the formation of which from the monococcus has just been described, may again subdivide, but in a different plane of cleavage from the first segmentation. This result gives four elements, and the single group is termed a tetracoccus, and many such groups tetracocci.

The single diplococcus may again divide in the same plane, and this process may go on indefinitely until a chain is formed, each link of which is adherent to the other in precisely the same manner as the two links are in the original diplococcus. When the elements divide in this manner, the result is a number of elements, one adjoining the other, but each element having still the delicate bridge of cellulose membrane as was described in the formation of the single diplococcus. Instead of a straight chain, occasionally an angle may be formed, or the chain may assume a serpentine course. From its fanciful resemblance to a chain, this formation is termed streptococcus, or streptococci.

The micrococcus again, instead of dividing to form a diplococcus, a tetracoccus, or a streptococcus, may so divide as to resemble a bunch or cluster of grapes, and Ogston, of Aberdeen, has termed the micro-organisms arranged in this form staphylococcus.

The micrococci finally may divide in such a manner as to form an irregular mass. These micro-organisms within the mass are held in a gelatinous matrix. This arrangement is termed zooglœa, or colony, and this variety is seen typically illustrated in metastatic abscesses.

The elements in the zooglœa mass are the same size, but the masses of zooglœa may vary in size.

Thus it is evident that the segmentation of the micro-organisms may be such as to form from the I, monococcus; II, a diplococcus; III, a tetracoccus; IV, a streptococcus; V, a staphylococcus; VI, zooglœa; and all of these different varieties are here present, and can be demonstrated at any time.



FIG. 3.

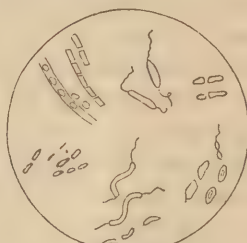


FIG. 4.

Bacteria.—Bacteria are short, thick, rod-shaped micro-organisms. Some bacteria possess cilia or flagella at one or both ends, which are rounded. They are capable of a certain amount of locomotion in fluids, which is one of the distinguishing features between them and micrococci. The power of locomotion is by the use of the flagella, and the ability of these special micro-organisms to move freely about seems to be favored in many cases by the presence of oxygen.

Bacteria multiply by transverse fission in a manner similar to the multiplication of micrococci. The longitudinal fission

does not as a rule occur in bacteria. The ends of the bacteria are slightly rounded. Bacteria are found in the torula form or in zooglœa, and, while it is possible to find in bacteria some of the other varieties belonging to the arrangement of micrococci, the three forms which have been mentioned will include the greater majority.

Bacilli.—Bacilli are rod-shaped micro-organisms with a square cut extremity. These rods are also invested with a cellulose membrane precisely the same as micrococci and bacteria.

Bacilli multiply by fission and by the endogenous formation of spores. Some varieties possess cilla or flagella by the use of which they are capable of locomotion. Bacilli are found in long filaments either straight or curved, but do not as a rule form into zooglœa masses, as micrococci or bacteria; they are destroyed if submerged under boiling water, and are also paralyzed by freezing, while the spores are not destroyed. The most important fact to remember in connection with bacilli is their multiplication and development by spores. In the long axis and in the rod-shaped bacilli a bright spot becomes visible, which soon enlarges until the tense expansion of the investing cellulose membrane causes it to burst, and the spore is set free. The number of cells in the protoplasmic mass will determine the number of spores liberated, and the presence of oxygen seems to be necessary in certain bacilli to excite this method of multiplication. It is said of anthrax bacilli that they never germinate by spores unless they are freely exposed to oxygen. Moisture is also necessary for spore development. If the spores which have developed from rod-shaped bacilli in the manner already described have sufficient nutrient pabulum, they will germinate again into bacilli; deprived of this, they remain as spores. It is to be remembered as an important fact bearing upon putrefaction in wounds, that while heating, freezing, drying, exposure to chemical irritants, etc., will destroy micrococci, bac-

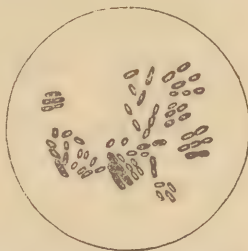


FIG. 5.—SPORE DEVELOPMENT
IN *BACILLUS ANTHRACIS*.

teria, and bacilli, the spores of bacilli seem to be able to withstand all such influences, and that after a lapse of an indefinite period of time the spores, under favorable conditions and circumstances and in suitable soil, can be made to germinate into bacilli. The explanation of this inherent power belonging to spores to resist influences which kill micrococci, bacteria, and even the bacilli themselves, is found in the anatomical and physiological arrangement of a double investing sheath or membrane enveloping the spore, an outer cellulose and an inner adipose membrane. The double membrane acts as a poor conductor of heat to the contents of the sac, and hence influences which destroy the vitality of micrococci, bacteria, and bacilli themselves do not affect the vitality of the spores. Thus bacilli, like micrococci and bacteria, multiply by fission, but the fission is usually transverse; but they also develop by spores, which may be said to be the important and distinguishing feature of the life history of bacilli.

Bacilli are invested by a cellulose membrane, and are capable of locomotion by the use of cilia or flagella, by means of which they can dart, navigate, and pirouette in fluids and solids over the field of vision.

Bacilli, like micrococci and bacteria, are destroyed by exposure to boiling water, by freezing, by certain chemical irritants, but the spores of bacilli are not destroyed by these influences. The spores, to develop into bacilli, require generally oxygen and always moisture. If the spores have a suitable soil they will germinate into bacilli; if not, they will remain inactive until a time when circumstances and conditions are favorable for their development.

If in any fluid, therefore, which has been subjected to a temperature of boiling water for a few moments, and later, subsequent to the boiling, there appear micro-organisms, these organisms will have developed from the spores of bacilli, because the micrococci, the bacteria, and the bacilli have all been destroyed by the temperature of boiling water.

Fungi.—Blastomycetes. By fungi are meant certain micro-organisms which are found to be the cause of putrefaction. The

fungi are contained in the air, water, tissues, soil, etc., the most common one of which is the penicillium glaucum. This is seen upon cheese and is popularly called the cheese-mold. Its spores are found in the air, and they are a common cause of contamination in cultivations of special micro-organisms and of putrefaction in wounds. In this flask is seen a typical cultivation of this mold.

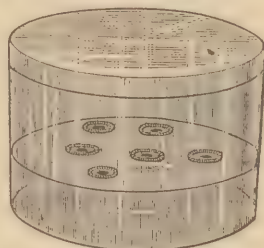


FIG. 6.—CULTURE OF PENICILLIUM GLAUCUM.

The aspergillus is another mold which is quite common. There are several varieties of this species. In this flask is the aspergillus albus, in the other the aspergillus niger.

Torula is another mold, and is commonly known as the yeast-plant. It consists of numerous cells which are larger than micrococci. Torula or yeast-plant multiplies by the budding of the mother cell, and possesses the power of separating sugar into alcohol and carbonic acid. It is the micro-organism which produces alcoholic fermentation. The several varieties of torula are beautifully illustrated in these flasks. The specimens were prepared by me from some cultures which I obtained in Edinburgh.

Besides these molds there are a great many others concerned in putrefaction, a large number of which are under cultivation upon these different media. In addition to the molds there are some micro-organisms which I have thought best to introduce in this connection, because the special micro-organisms involved in a specific fermentation can then be grouped together in one place. Wherever there is fermentation in animal matter it is designated putrefaction. Pasteur assigns the reason for calling this variety of fermentation putrefaction "because of the evolution of the gases, which are derived from sulphur and phosphorus, due to the decomposition of fibrine, of albumen, of blood, of gelatine, and of the substance of the tendons."

Among these micro-organisms may be mentioned the vibrio, which appears as a curved rod-shaped organism. It is often

found more or less tortuous. This germ is concerned in the lactic fermentation of milk, just as the torula is concerned in the alcoholic fermentation. One peculiarity of the vibrio is that it does not thrive well in oxygen, which gas is so essential to most micro-organisms. This fact explains the reason why milk, for example, if exposed to fresh air in a cool place will for a long while resist putrefaction.

In these test-tubes which contain milk has been introduced a certain quantity of a saturated solution of boric acid, and this milk has thus been kept for weeks in this laboratory free from any putrid changes.

The vibrio of butyric acid, another micro-organism which concerns the surgeon, consists of cylindrical rods. It lives without air, and air prevents the butyric fermentation with which this micro-organism is associated.

Still another micro-organism, also of interest to us, is the *mycoderma aceti*, a beautiful growth of which is in this bottle. It is a well-recognized fact that in a half-filled bottle, with the cork withdrawn, wine will become sour. Now, the essential difference between wine and vinegar is that the latter contains no alcohol, which is the essential factor in the manufacture of wine. When wine is distilled, alcohol is obtained; when vinegar, acetic acid. The *mycoderma aceti* is the ferment of vinegar, and this fungus is deprived of all functional activity by exposure to a heat of 60° C. No wine subjected to such a heat and hermetically sealed will ever become sour; but let it be exposed to the ordinary air it will soon become sour, because the *mycoderma aceti* which exists in air has gained entrance to the wine (which before this was prevented from becoming sour owing to the fact that the micro-organism was destroyed in the heating). Connoisseurs always keep their wines in bottles lying flat, and never standing. The reason of this is obvious, as Pasteur has pointed out, when wine is kept in bottles standing there is a chance for air to filter through a dry and permeable cork, and then again there is a space in the neck of the bottle which contains air derived from filtration through the cork, and upon the surface of the wine the *mycoderma aceti* can

produce the fermentation which characterizes this variety of micro-organisms. If, on the other hand, the bottles of wine are kept lying flat, there is no space for air to collect in the neck of the bottle, and the cork being constantly moist expands instead of shriveling, so that the *mycoderma aceti* contained in the wine are deprived of a proper amount of oxygen. The small amount of air which filters through the cork under these conditions is appropriated by oxidizable constituents of the wine. The *mycoderma aceti* is a most common micro-organism, found in the air and in wine in very great abundance.

2. *The action of these micro-organisms upon fluids, solids, inorganic matter, and upon living tissues.*—In the consideration of the first division of our subject an attempt was made to discuss the existence of micro-organisms more from a morphological than from a physiological point of view. In treating the second division of our subject an attempt will be made to confine the discussion to the functional activity of these micro-organisms, and in doing this the action of these micro-organisms will be discussed first upon the fluids, then upon solids, then upon inorganic matter, and finally upon living tissues.

It has been already demonstrated that micro-organisms exist in the air, and if now any fluid—for example infusion of beef—be allowed to stand a few days in several test-tubes, the fluid will become turbid; later molds and bacteria will be found upon the surface, and the color of the fluid unmistakably changed, and the odor very offensive. In common parlance, it is said that the fluid has decomposed. This fluid has been examined by the microscope, and it is swarming with bacteria moving all over the slide by the use of the cilia or flagella. This simple experiment is repeated daily, and it is perfectly well known that any fluid left standing in a vessel will decompose. To show now that the cause of the putrefaction is due to the action of these micro-organisms in the air, and not to the air itself, I will here repeat the experiment which has been made by Professor Tyndall. This scientist constructed a box, an exact model of which I have had made in London for the very purpose.

This box, then, which contains about two thousand cubic inches, is constructed with a glass front.

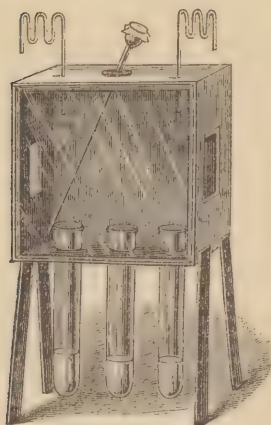


FIG. 7.

Upon the sides are two windows directly opposite to each other. Upon the top is a small hole about two inches in diameter, which is made air-tight by a piece of India rubber stretched over the aperture and sterilized cotton under it. The interior of the box is smeared over with glycerine to collect the dust as it settles. A long, slender pipette is thrust through the center of the opening closed by the India rubber. The upper part of the pipette is patent, and fluid is poured into the test-tubes in the box by this pipette. On both sides of the pipette and a short distance from it are two bent

tubes which connect the interior of the box with the external air. The tubes are bent so as to catch and hold any particles in the air which might be carried by currents of air set in motion by the difference of the temperature between the interior of the box and the external air. The floor of the box is perforated to receive three air-tight test-tubes into which has been poured the fluid that is to be exposed to the action of germless air. After having allowed the box to remain undisturbed for ten days I closed it, and by placing a lamp in front of one of the side windows in a dark room one could see that the rays of light sent out from the lamp traveled across the box and emerged from the opposite window and were visible as they radiated from this window into ethereal space. The fact that a beam of light was visible in the box between the two windows was proof that the air within the box was full of micro-organisms which appear as floating matter. A few days later I applied the same test with the electric light, and found that, while the beam reflected from the lamp was visible from the burning flame to the side window of the box, and from the

opposite window into ethereal space, the beam was not visible in the passage across the box from window to window. This was proof that in the interior of the box the air contained no floating matter. I shall have to ask you to accept this physical law which Professor Tyndall so beautifully illustrates, that the pure gaseous portion of our atmosphere is incompetent to scatter light, hence the air contained within the box was not competent to scatter the beam of light from window to window because the air was purely gaseous, hence optically pure, and did not contain floating matter, which is the *sine qua non* for the passage of a beam of light.

To return now to the box, in which is contained only gaseous air with no floating matter except such as clings to the interior of the box, which is painted over with glycerine to catch the few particles of organic matter which by subsidence gravitates to the bottom and sides of the box.

I introduced the fresh beef infusion by pouring it from a sterilized and clean graduate into the empty tubes through the pipette. The test-tubes were then immersed in an oil bath which was boiled for a few minutes. The uncondensed portion of the vapor which arose from the fluid in the tubes passed out through the bent tubes on the top of the box. Before the boiling was stopped plugs of sterilized cotton wool were inserted in the open ends of the bent tubes, so that the slight current of air caused by the cooling of the air-chamber would not attract the outer air with its floating matter, but after a while the plugs were removed. In this manner the fluid within the test-tubes was freed from micro-organisms, and the air within the box contained no organic matter.

I shall now call attention to the fluid within these protected test-tubes, and it is observed that the fresh beef infusion in each test-tube is perfectly clear and transparent, just as it has been for weeks and weeks, and that there is not the slightest turbidity or mold present, as is the case in every one of the test-tubes which was not protected from the air which contained organic matter. The mere presence of limpidity need not be accepted as a proof of the absence of bacterial life in the fluid

contained in these protected tubes, since there are other proofs which are absolutely incontrovertible. I asked Dr. Biggs, the instructor in the Carnegie Laboratory, who is a skilled microscopist, to examine this fluid with the most powerful lens in the laboratory, and he failed to find the slightest trace of organic life in the fluid. By repeated attempts no cultivations can be made from this fluid, as it contains no life from which life can be developed. If life exists in this fluid, cultivations of the organisms from it in a nutrient pabulum would soon develop life. If further proofs of the absence of bacterial life are needed, the concentrated solar beam will be found incompetent to scatter light, and hence living organisms can not be present in this fluid; and finally, the demonstrative proof by the use of Nicol's prism would cause any particles of organic matter contained in this limpid fluid "to flash out with greater force because of the increased darkness of the space around them."

The other tubes, which were not protected from air containing micro-organisms, exhibit changes which indicate the presence of living organisms. The fluid is turbid; the microscope reveals colonies of micro-organisms; these germs have been cultivated in suitable soil and they develop and grow; the use of the concentrated solar beam and Nicol's prism is attended with vastly different results from the former experiments.

If this box is examined years hence, it will be found that the beef infusion in the test-tubes is clear and free from any signs of decomposition, just as it was months ago when introduced into the tubes. Subject this fluid to the test of the microscope, and the microscopist will be unable to trace any evidences of bacterial life. The test of the solar beam is a more accurate one from a scientific point of view than even the microscope itself, because the beam of light will detect what the microscope is unable to reveal. The condensed solar beam reveals to us a world held in suspension, too infinite for the microscope with its limited powers, and demonstrates that there is a realm of organic life beyond the power of the microscope to unfold.

Examine now in contrast fluids outside of the box, in tubes

put up at the same time, and they are turbid. The practical conclusion which is to be drawn from the behavior of these fluids contained within the test-tubes, some of which were exposed to the external air and some of which were placed in the box protected from air which contained organic life, is this, that the micro-organisms which float in the air are the cause of putrefaction, and if the fluids can be protected from the air containing micro-organisms they will never putrefy; if exposed to ordinary air they will always putrefy. Putrefaction, then, is caused by micro-organisms contained in the air and not by the air itself.

In proof of this startling assertion I have here some pipette-bulbs which were filled by me during the past summer. They contain infusion of beef and of turnip, and the fluid is as pure and uncontaminated as the day when they were hermetically sealed during ebullition. This fluid will keep forever without putrefaction, but let a single micro-organism gain entrance with the air through an opening too diminutive to be visible by the naked eye, and in a few hours the infusion of beef will become slightly turbid and be swarming with bacteria. Out of the twelve tubes thus filled and hermetically sealed during ebullition, only one has shown signs of decomposition, and this is due to an error in manipulation on my part. These tubes I sealed in Professor Tyndall's laboratory at the Royal Institute in London, and I am indebted to Mr. Cottrell, Professor Tyndall's assistant, for his kind attention and courtesy. The infusion in these pipette-bulbs will keep forever pure and uncontaminated. At the meeting of a scientific body held in England during the past summer, Mr. Cottrell exhibited three pipette-bulbs which were hermetically sealed by him ten years ago, and while carrying them from the Royal Institute to Cardiff the end of the nozzle of one of the tubes was broken off, and the opening was visible only by the closest examination. In three hours the infusion which had kept clear for ten years became turbid. This



FIG. 8.

accident, as provoking and disappointing as it was, illustrates in a most forcible and impressive manner the fact that decomposition in a fluid is caused by the entrance of the germ-laden air, and that the quantity of the air is unimportant, while its quality is significant. Pasteur has shown that such flasks may be opened for a time without any turbidity appearing, and suggests, as an explanation of this fact, the non-continuity of the cause, for these germs appear in clouds, and if the flask is opened in the interspace of a bacterial cloud, decomposition will not occur until germs come in contact with the fluid. Thus my statement of the law is amply proved. It is not sewer gas, then, that provokes epidemics, but the germs in that medium which produce the mischief; so that if the germs be destroyed the gas is perfectly innocuous.

The effect upon living tissues is precisely the same as upon sterilized jelly or upon the infusion of beef. If any of the



FIG. 9.

germs in the air fall upon an unprotected wound, just so sure will decomposition take place. Further proof of the assertion already made, that fluids which are kept from the air containing micro-organisms will not decompose, may be adduced by the examination of these six test-tubes which were filled with Koch's jelly. They are as clear and transparent to-day as they were when hermetically sealed in this laboratory last summer. This experiment may be repeated over and over again and with invariable results. In the hermetical sealing of tubes in the laboratory the conditions are most favorable for the entrance of germs because they are there present in great abundance. Now, in this flask may be seen growing innumerable forms, which have gained entrance to this

jelly through the sterilized cotton plug which has never been removed since the flask was filled with Koch's sterilized jelly.

The clinical fact that germs capable of producing putrefaction may gain access to a wound through a surgical dressing is thus forcibly shown. Hence it is of the highest importance that the surgeon should take great care in the selection of his antiseptic dressing, should display much ingenuity in the manner of its application to different wounds, and should exercise mature judgment in regard to the proper time of a renewal of the dressing.

Meddlesome interference with a wound is just as productive of mischief as protracted delay. A surgical dressing should be changed after a suitable period has elapsed, and at any time when the indications are present of some disturbance in the wound, but on the other hand it should not be disturbed within a week if the wound be aseptic, no discharge be present, and no discomfort be experienced.

Take any wound in yonder hospital and expose it to the air containing micro-organisms, and putrefaction will occur upon the surface of the wound. The area and extent may be influenced by circumstances, for there are, of course, exceptions to this law; but let the air be foul and the wound be kept unclean, and decomposition will be sure to follow, and sepsis will be the result.

Professor Lister has beautifully illustrated this in demonstrating that air contained in the pleural cavity, which has passed through the lungs, will never produce putrefaction if it comes in contact with an internal wound. The explanation of this is found in the fact that air which has been filtered of germs in its passage through the lungs has become innocuous. The air in the pleural cavity having passed through the air passages and lungs, one of whose functions is to arrest dust, has been prevented from entering the tissues. But ordinary air coming in contact with an internal wound would be most serious. As you see, the lungs act in the human being in the same manner as the box acts in the experiment just presented for your consideration. It makes little difference whether you employ the strict antiseptic dressing of Lister, or the eucalyptus oil of Schulz, or the continuous irrigation of bichloride of mer-

cury as practiced by Schede, or the naphthaline dressing of Fischer, or the salicylic method of Thiersch, or the open method of Wood, as long as the great principle is observed of preventing the action of the micro-organisms contained in the air from causing putrefaction in a wound. All these different methods of surgical dressing observe one grand principle, which is the prevention of putrefaction, just as all roads lead to the king's highway.

The study of fermentation, as it affects surgical wounds, would be incomplete without some reference to the way by which Pasteur was led into an investigation of this great theory. Pasteur's studies, up to the time of his appointment as Dean of the *Faculté des Sciences* at Lille, had been devoted to chemistry and molecular physics, and it was in the elaboration of these sciences that his great reputation was made. He explained "the influence of molecular dissymmetry of natural organic products," and pointed out the difference which exists between the chemistry of inorganic and organic matter. When he was made Dean of the *Faculté des Sciences* at Lille, he resolved to enter upon the study of fermentation. The manufacture of alcohol from beet-root and corn was the chief industry of that part of France. His discovery of the law of molecular dissymmetry and its relation to microscopic organisms suggested to his mind the fact that fermentation might be due to microscopic organisms. With this end, he began his studies as to the nature of fermentation, the result of which, in their application to surgery, has proved an inestimable boon to the human race.

The subject of the relations which micro-organisms bear to the ætiology of disease would be incomplete also without an allusion to the process of fermentation. In speaking of the existence of micro-organisms, mention was made of a class chiefly concerned in fermentation. Now, as a wound is liable to be contaminated by the micro-organisms, which produce fermentation, it is necessary to discuss this subject as briefly as is consistent with its relations to wound-treatment. In order to understand what changes may occur in a wound on account of the access to it of certain micro-organisms contained in the air, which will cause

fermentation, it is obvious that attention must be called to the special action of these micro-organisms upon fluids and tissues.

The best example, and the most familiar one to illustrate fermentation, is the process of wine-making. During my sojourn in Heidelberg I became much interested in the manufacture of Rhine wine, and was afforded ample opportunities for a study of this interesting subject through the kindness of Mr. Ellmer, who controlled large vintages. If any of the fresh fermented grape-juice is taken from the wine-vats and examined under the microscope, it will be found to contain a small micro-organism which is called *torula*, a beautiful specimen of which I show here sprouting upon sterilized bread-paste. This micro-organism I sowed in this culture-medium during the past summer, having collected it from the highlands in Scotland. It grows under favorable conditions, and buds in a most luxuriant manner. A visit to the champagne district at Epernay, near Paris, will also reward one with much knowledge upon this fascinating subject. Why grapes when crushed and left in open vats would ferment was a problem which remained unsolved for centuries, until Pasteur made this great discovery. He showed that, when the grapes were ripened sufficiently for the wine presses, upon the skin of the grapes, and upon the stems, were found infinitesimally small particles which, when examined under the lens of the microscope, were seen to be living cells or micro-organisms, and that when these micro-organisms were sown in the juice of the grape the *torula* grew and developed in rich profusion. The growth of the *torula* in the grape-juice was associated with active fermentation. During the past summer, while visiting with my friend Dr. Glover, of London, an old and interesting town in a dairy district in England, I saw in the oldest chemist shop in Great Britain an advertisement of a solution for preserving milk. I was told by the present chemist that the solution was sold in large quantities to the farmers in the vicinity. Upon inquiring, I found it to be only a saturated solution of boric acid. If milk is permitted to stand in a glass it will soon become sour; but if there is added to the same quantity of milk which is contained in a

glass beside the other a little of the boric acid it will be found that the lactic fermentation will not take place, and that the milk will not become sour. The reason why this milk in the first glass ferments is owing to the development of the micro-organism known as vibrio, which has been mentioned among the list of micro-organisms, and which is present in this test-tube, and the reason why the milk in the second glass remains pure and sweet is on account of the absence of the vibrio which causes the lactic acid fermentation.

If a pair of shoes be exposed to the air for a length of time the shoes will be covered, as these shoes upon the table are covered, with the mold (*penicillium glaucum*), which has simply found a suitable soil for its development.

Expose a piece of raw meat upon a warm day to the air and soon it will be foul and swarming with bacterial life; keep the meat from heat and expose it to cold and this will keep the meat fresh, because cold checks the development of the bacteria which produces the fermentation. I have often been astonished to see how for weeks fish, joints, and fowls are thus preserved by suspending them in a cold atmosphere upon the Atlantic steamers. Let these perishable articles of food be hung for a single day in a room with ordinary temperature of one of our July or August days, and they would soon swarm with bacteria. If the meat is where flies can gain access to it and deposit their eggs, very soon maggots will be found upon it. The same is possible though not probable in the case of an open wound. The surgeon must protect it from the assault of these innumerable micro-organisms, or the wound will be the birth-place of millions of germs which will cause it to undergo putrefaction. Only during the past week I saw a patient with a bedsore, and maggots were thick upon the surface of the wound; when the patient was brought under proper influences, the wound became free from living organisms. The same bacteria that causes decomposition in the piece of raw flesh will attack the wound; the same micro-organism that produces fermentation in milk or in wine, or that grows upon the old pair of shoes, will be sown upon it.

3. *The specific action of micro-organisms to produce surgical diseases.*—In order to prove that a special organism is the cause of a special disease, it is necessary that every investigation into the etiology of a disease must conform to a certain Procrustean method, which, in brief, is enunciated by Koch as follows:

(1) The micro-organism must be invariably found in the blood or tissues of the diseased animal. (2) The same micro-organism must be capable of artificial cultivation for several generations. (3) The artificially cultivated micro-organism, when introduced into an animal, must produce the same disease as that from which the germ was derived, and this same micro-organism must finally be found in the inoculated animal.

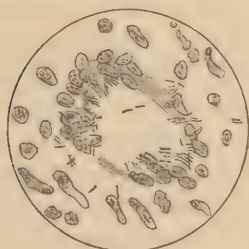


FIG. 10.—BACILLI TUBERCULOSIS
IN TISSUE.

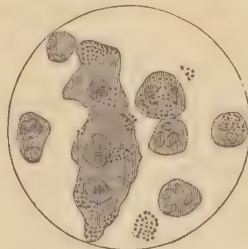


FIG. 11.—GONOCOCCI IN GONORRHEAL
PUS.

Without any investigation conforming to these propositions the case can not be said to be proved. These conditions have been verified in anthrax bacilli, in the bacillus tuberculosis, in cold abscess, in the micrococcus of erysipelas, and in the gonococcus of specific urethritis.

There are also a few other surgical diseases in which, while the facts are not proved, they are extremely probable: leprosy, glanders, farcy, gangrene, pyæmia, and septicæmia. All these special organisms are here under cultivation in these glass tubes. There are, of course, other diseases not surgi-

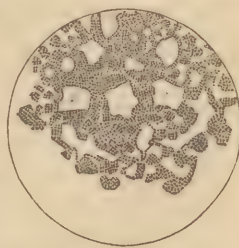


FIG. 12.—MICROCOCCI OF
ERYSIPELAS.

NOTE.—I am indebted to Mr. Shively for these drawings.

cal where the cause of the malady is clearly proved to be due to the special micro-organism.

The cholera germ, the typhoid fever, the diphtheria, the pneumonia, and other germs are in these tubes. These cultures have been made by Dr. Biggs, to whom much credit is due.

In this department of surgery there is a vast field of unoccupied ground, and it is to be hoped that the Carnegie Laboratory will be the birth-place of the discovery of other micro-organisms which can be shown to stand in a causative relation to surgical disease. It might be interesting in this connection to refer briefly to some of the better known micro-organisms concerned in closed suppuration; but a full discussion of this subject will be referred to a future article. There are in these test-tubes, and upon these culture-plates, cultivations of the micro-organisms found in the different acute suppurative processes; among which the more important ones are staphylococcus pyogenes aureus and albus, and micrococcus pyogenes tenuis, streptococcus pyogenes, staphylococcus cereus flavus and albus; also, the micrococcus of Fehleisen, which has been demonstrated to be the cause of erysipelas, the gonococcus of specific urethritis, micrococcus found in noma, on cancerum oris, and many others of great surgical interest.

There are many signs which betoken clearly that in the United States the profession of medicine is at the beginning of a great epoch in medical education, and that the scientific part of medicine is to be brought forward, and that it will receive the prominence which is its due. This object is attainable only through the advantages which scientific laboratories offer to the profession. The Sloane laboratory at Yale, the Carnegie and Vanderbilt laboratories in New York, the biological laboratories at Princeton and Harvard and Baltimore, besides several new ones in the process of building, all speak in unmistakable terms of the great interest which is centering in medical education.

4. *The methods which the surgeon possesses to destroy micro-organisms in wounds.*—This final division of our subject natu-

rally leads us to a consideration of some of the important principles involved in wound treatment. In this connection, however, only a general survey of the subject can be made, for space and time do not permit of a discussion. From what has been said and demonstrated this evening, it is obvious that micro-organisms are the causes of putrefaction, and that a surgeon to avoid putrefaction must destroy the life of these germs without producing any injurious effect on the tissues. In the discussion of the anatomy and physiology of these micro-organisms it was stated that boiling, freezing, and certain chemical irritants destroyed the vitality of micrococci and bacteria and bacilli, but not always the spores of bacilli. It is evident that neither boiling nor freezing water could be employed by a surgeon during an operation, but he must look to the efficacy of some chemical irritant which will be innocuous to living tissues to accomplish this result. Koch has demonstrated that a solution of one to three thousand bichloride of mercury is quite sufficient to destroy all the micro-organisms, including the spores of bacilli. The same investigator has also shown that a five-per-cent. solution of carbolic acid will destroy nearly all the varieties of micro-organisms, and even some of the spores of bacilli. Hence it is obvious for all practical purposes that these germicides may be used with great certainty. It is a noteworthy fact that carbolic acid is volatile, which can not be said of bichloride of mercury. In the open treatment of wounds the very highest type of antiseptic surgery is found. The frequent use of carbolic-acid solutions renders the soil unsuitable for the growth of micro-organisms; the unobstructed flow of the discharge from the wound does not permit the secretion to become putrid; the exposure of the wound permits evaporation, which renders the discharge too highly concentrated for the favorable growth of these germs; and finally, as Pasteur has pointed out, this same free exposure by the supply of oxygen to the micro-organisms prevents them from disorganizing and breaking up the albuminous compounds in their struggle for one of the essentials of their being. The preservation of the albuminous compounds diminishes, and even prevents, the processes of putrefaction in a wound. An exposure of the

wound lessens the chances of decomposition by causing the wound to become dry. I have often been criticised as inconsistent in advocating antiseptic surgery and at the same time recommending in certain wounds the open method. There is no real inconsistency at all. I believe in primary intention whenever possible, and consequently in closure of the wound; but there are wounds where primary intention can not under any circumstances be secured, and under such conditions a wound may be left open for repair, while antiseptic surgery is at the same time practiced.

I have seen during the past few years several cases of engrafted diphtheria upon a stump, when an epidemic prevailed in the immediate neighborhood. All of the wounds so complicated did well by free exposure to the air. In these cases the oxygen in the air interfered with the vitality of the putrefactive bacteria.

In some forms of bacteria, oxygen, on the other hand, is essential to their life. Hence, it should not be understood that antiseptic surgery be limited to a Lister dressing, but that antiseptic surgery is clean surgery, and that to Sir Joseph Lister more than to any other surgeon belongs the honor of having pointed out the cause of putrefaction in wounds. Another great advantage to be derived from the open treatment of certain wounds, where primary intention can not be secured, is the beneficent influence of the rays of the sun. Ten years ago I was in the habit of giving a stump a sun-bath. Now, again, quite recently, a scientific man engaged in bacteriological studies has demonstrated that certain pathogenic micro-organisms were killed by prolonged exposure to the rays of the sun. This reconciles the practice with the subsequent facts.

A most important study in connection with this subject is the selection of a suitable antiseptic. In these flasks which contain sterilized bread-paste I have made the paste succulent with different antiseptics kindly prepared by Mr. Rice: Carbolic acid (1 to 20), bichloride of mercury (1 to 3000), iodoform and naphthaline (saturated solutions), also sulphurous acid and many others. In these flasks, cultures have been made, and points of

infection have developed according to the strength and value of the different germicides. It does not follow that the most powerful germicide is the best antiseptic for wounds. The selection of one can be made by the surgeon after testing the merits of each as regards the germicidal power, and next as regards the effect upon living tissues.

In conclusion, if any surgeons present are still skeptical as regards the germ theory of inflammation, I can earnestly recommend them to take up the subject for investigation, and pursue its study along the same lines that I have pointed out in my demonstrations to-night, and I have no fears as to the conclusions at which they will arrive.

In this vast country, where surgeons are untrammelled by old and worthless traditions, where Continental propinquity does not arouse feelings of national jealousy, where a liberal, unprejudiced, and receptive condition of mind enables us to accept every good from every source, where unequaled laboratory advantages with rich abundance of material are offered, where earnest and enthusiastic investigators are fast coming to the front, we would predict a great and glorious future for American surgery.

With a view to promote this great future in American surgery, I would recommend the construction of an ideal operating theatre in connection with every hospital, and independent of the main building. The theatre to be so constructed with floor, side-walls, and ceiling as to permit the discontinuous inrush of hot steam a few hours before every operation, and at the time of the operation to have the room brought to a proper temperature for surgeon and patient. This would afford the surgeon an opportunity to operate in an air uncontaminated by living organisms. It would afford to the patient absolute protection from his unseen enemies, which hover over him at such a crisis. I would recommend for the accomplishment of this great future for surgery the use of antiseptic solutions prepared after chemical formulæ, and employed in the way of constant irrigation from the beginning to the end of the operation. This would afford protection from any local contamination in the wound itself.

Further, I would suggest the use of approved antiseptic dressings, which can be rendered invulnerable to the attack of any of such micro-organisms as these before us. Again, I would emphatically advise the employment of instruments so made as to permit of special disinfection in glass trays during the operation. Instruments should be made for this purpose with smooth metallic handles to withstand the action of the solutions in which they should lie before and during an operation. Still again would I recommend the use of thoroughly new and disinfected sponges, blankets, sheets, towels—everything which comes in contact with surgeon or patient—and last, not least, would I insist that all assistants and nurses be subjected to the most rigid disinfection.

Drainage.—In every large wound some provision should be made for drainage, and this object can be obtained by the use of suitably-prepared tubes, as practiced by Mr. Lister, or by a method known as capillarity, which was introduced by Professor John Chiene, of Edinburgh. The former method is specially adapted to large wounds, and the tubes can be made of red rubber, which is free from sulphur; the black tubes, owing to the presence of the sulphur, stain the dressings. The tubes in question have small apertures cut upon them at short distances from each other. They should be well introduced into the bottom of the wound cavity, and should not project beyond the surface of the skin. They can be shortened as the wound cavity fills up, or can be removed in a few days.

The method of drainage by capillarity consists of strands of cat-gut. Neuber's decalcified tubes and McEwen's chicken-bone drainage-tubes are apt to collapse or to become absorbed before their work is completed. Horse-hair is extremely useful in such wounds as are made in osteotomy, or where the extent of the wound is not great. The cat-gut is absorbed after its function has been completed, and is the best kind of drainage-tube for wounds of the brain. The cat-gut drain is not to be employed in any wound where there is suppuration, for the blood or serum can only be drained by means of these threads. The joints can be best drained by capillarity by horse-hair,

which is to be entirely withdrawn from the joint, and never left as is cat-gut in a wound cavity. Whatever kind or method of drainage is employed, the material to carry out drainage should be kept in carbolic acid (1 to 20), and should be dipped into bichloride of mercury (1 to 2,000) before being introduced into the wound.

I have lately used ivory drainage-tubes because the rubber tubes would often collapse, and in two cases within a month I have found, in gently withdrawing the latter, that a small piece of the end would tear off and be left behind in the cavity of the wound, to the bottom of which the end had become adherent. In the two cases just mentioned the wounds were opened, the pieces removed, and the wounds healed by granulation. To prevent this tearing off, and also to avoid the collapse of the tube, led me to resort to the ivory drainage-tube, and so prevent the mishaps just mentioned. These ivory tubes can be obtained of Mr. Ford, who has kindly afforded me some valuable assistance in my search for an ideal system of drainage in large wounds.

This variety of tube, previously bored and polished interiorly as well as exteriorly, I have employed with great satisfaction. In the first place, this tube can be made perfectly aseptic at any time and at all times, and thus may be used in any number of cases. In the second place, they will neither collapse nor soften as do the chicken drainage and the red rubber tubes. In the third place, they will neither act as irritants nor break off on withdrawal as do rubber tubes. In short, the only disadvantage which presents itself to my mind is the inability of curtailment when the tube requires to be shortened day by day. The compensatory advantages, however, far outweigh this difficulty.

Finally, nurses and assistants in an operation should be thoroughly imbued with an unswerving faith in antiseptics, and they should be willing to carry out with religious zeal the necessary rites of personal cleanliness in every operation. With all these adjuvants, and I include also perfect anaesthesia, our science can extend to suffering humanity such beneficent aid as our forefathers, with their crippled resources, could never have given.

The acceptance of the germ theory of inflammation makes possible the opening of joints, the wiring of compound fractures, the resections of the stomach and intestines, the removal of the kidney, the extirpation of the spleen, the washing out of an abscess of the lung, the extirpation of tumors from the brain, the removal of gall-stones, and the opening of the peritoneal cavity, to say nothing of a long list of operations of this character, which, but a decade since, were considered not within the pale of lawful surgery. These measures for relief are now adopted with almost the certainty of uniform result. Before the principles of antiseptic surgery became deeply rooted in the minds of surgeons, patients were doomed to unnecessary suffering, the avoidance of which in these days is the masterly triumph of the grandest profession in the world.

